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# Analysis of Dynamic Behaviour of a DFIG based Wind Turbine during Grid Fault using DC Chopper Protection

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## Abstract

**As demand of energy is increased very fast in the world, installed capacity of wind turbine increased rapidly. Doubly fed induction generator (DFIG) is popularly used in wind turbine application due to its many advantages. When grid voltage is reduced due to fault, dc chopper connected in parallel to dc-link capacitor is activated. In this paper the effect of dc chopper is highlighted to control the rotor current and dc-link voltage. Simulation results are based on MATLAB-SimPower System.**

### Keywords

DC chopper, Doubly fed induction generator (DFIG), Low voltage ride through (LVRT), Wind turbine (WT)

## Introduction

As the electricity demand increasing very fast, more generation is required to be installed in to the grid. New generating units suggested for renewable energy resources because it is clean, abundant and economical. Among all other energy resources wind energy is fastest growing energy resources. There are several types of wind turbine generators used, DFIG is one of them. DFIG based wind energy conversion system has advantages of reduced converter rating, variable speed operation and capable of regulating active and reactive power separately.

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The stator of the DFIG is directly connected to grid and rotor is connected to grid via back-to-back voltage source converters. With increasing dispersion level of WTs into the grid, the wind power grid connection codes in most countries need that WTs should remain connected to the grid to maintain reliability during and after a short term fault [1]. Ability of WT to stay connected to gird during grid fault is known as low voltage ride through (LVRT) capability. During fault on the grid, grid voltage collapsed, causing sudden increase of stator current of the generator, due to mutual coupling between stator and rotor circuit rotor current also increases [2]. This excessive rotor current flows through the rotor side converter (RSC) and damage the dc-link and the converters. Some techniques of protection are required to prevent converters from the damage due to high current in rotor circuit. The performance of the proposed system is studied during steady state, and during asymmetrical fault (three phase to ground fault) with and without dc chopper circuit.

## Case Study

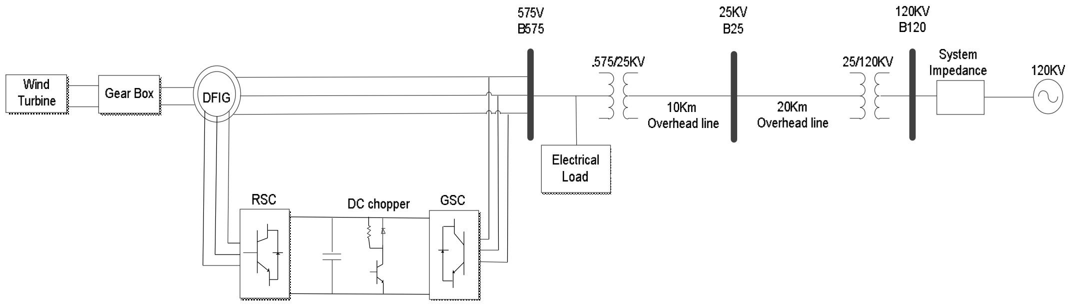


*Figure 1: System Configuration*

As shown in figure 1, a WT connected to DFIG having capacity of 1.5MW is considered for study. Pitch control is used for the study. WT connected to 25kV bus via a 575V/25kV, 2MVA transformer. This DFIG based WT connected to grid of 120kV via a 120kV/25kV, 47MVA transformer. A resistive load of 1.5MW is connected at bus B575. Main parameters for the DFIG are described in [3], [4].

The DC chopper made of power resistor which is connected in parallel to dc capacitor through a power switch. The power switch will be turn off if the dc bus voltage is within prescribed limits. DC chopper connected in parallel with the dc-link capacitor to protect it from the overvoltage during the low grid voltage [5]. When dc-link voltage surpasses the threshold value dc chopper will be on and RSC still connected to the rotor of the DFIG, and when dc-link voltage drops to threshold value dc chopper will turn off. Figure 2 illustrates the proposed dc chopper control. An enable signal is fed to switch to activate dc chopper, if dc bus voltage, $V_{dc}$ exceeds threshold value, $V_{dct}$.

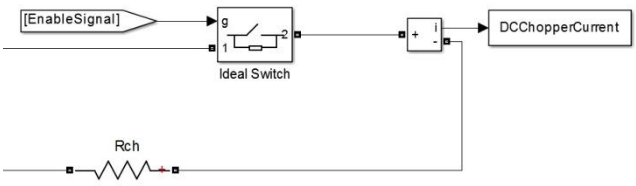


*Figure 2: DC chopper protection circuit*

DC chopper resistance chosen such that it should be small enough a large voltage at converter terminals can be avoided and high enough to limit rotor current and dc-link voltage within threshold values. DC chopper control scheme proposed in this paper illustrated in figure 3. In the proposed work an enable signal is generated, when rotor current $i_r$, exceed the threshold value $i_{rt}$, or if the dc-link voltage, $V_{dc}$, exceeds the threshold value $V_{dct}$.

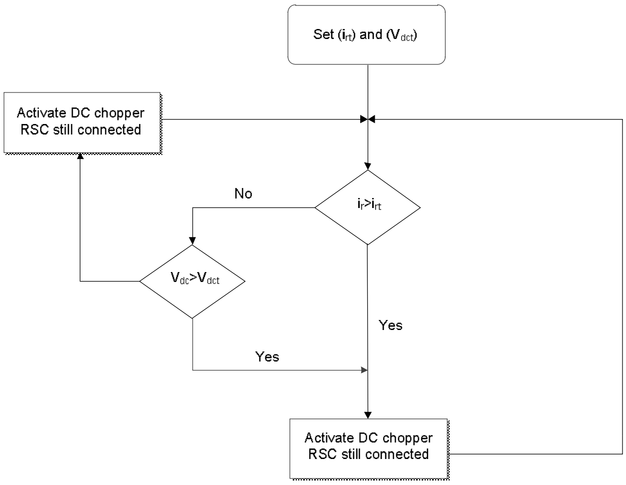


*Figure 3: DC chopper control flowchart*

# Simulation Result

The proposed method is simulated on MATLAB-Sim Power System. A three phase to ground fault is simulated at 25kV bus B25, which is known as point of common coupling (PCC).The applied fault is initiated at t=11s and cleared at t=11.1s. The dc-link voltage is set to 1150V. The threshold value for the dc-link voltage and rotor current is set at 1800V and 1.5pu, respectively. Study is done for with and without activating the dc chopper circuit. A constant wind speed of 12 m/s is considered for both the cases.

## System without DC chopper circuit

A three phase to ground fault is initiated for 100ms at bus B25 without activating the dc chopper circuit. For grid code requirement, the back-to-back VSCs of the DFIG are controlled to feed reactive power to grid during the grid fault [6]. Due to sudden fault at PCC, grid voltage is reduced to zero and stator voltage is reduced, as shown in figure 4, to a value that is corresponding to the reactive power fed from the DFIG. During fault, dc-link capacitor is discharging as given in figure 4. During the fault active power is zero and DFIG is controlled to feed reactive power to the grid as portrayed in figure 5. The rotor maximum value reaches more than three times the nominal value as shown in figure 6. Electromagnetic torque and generator speed are portrayed in figure 7, during fault.

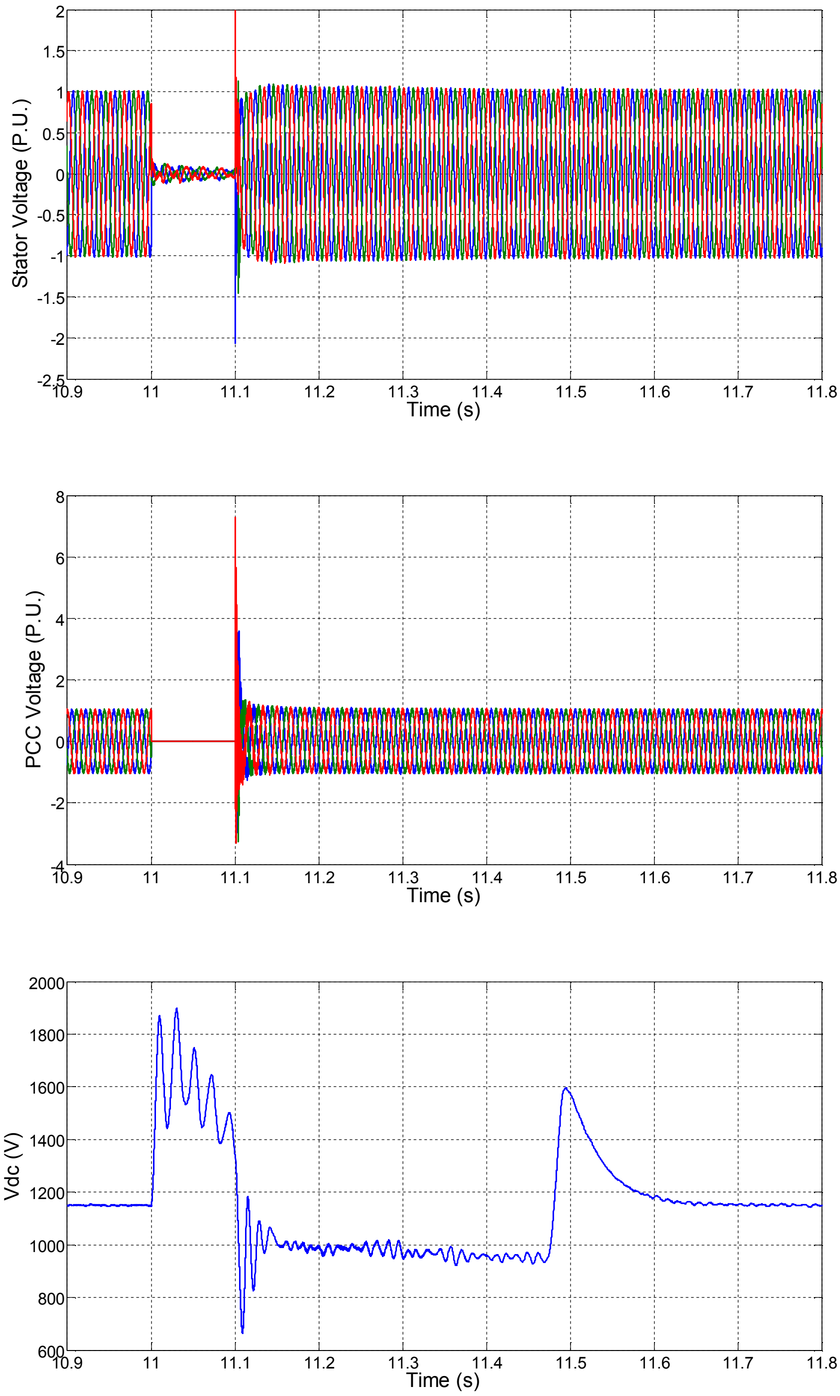


*Figure 4: Stator voltage, PCC voltage, and dc-link voltage*

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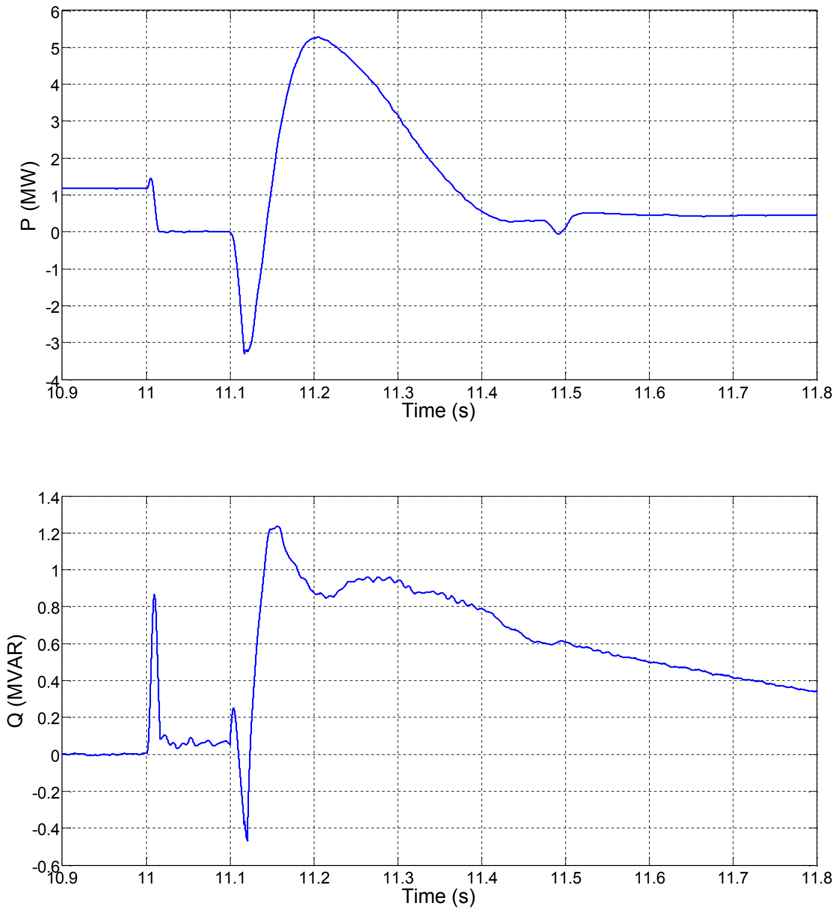



*Figure 5: Active and reactive power fed to grid from the wind turbine*

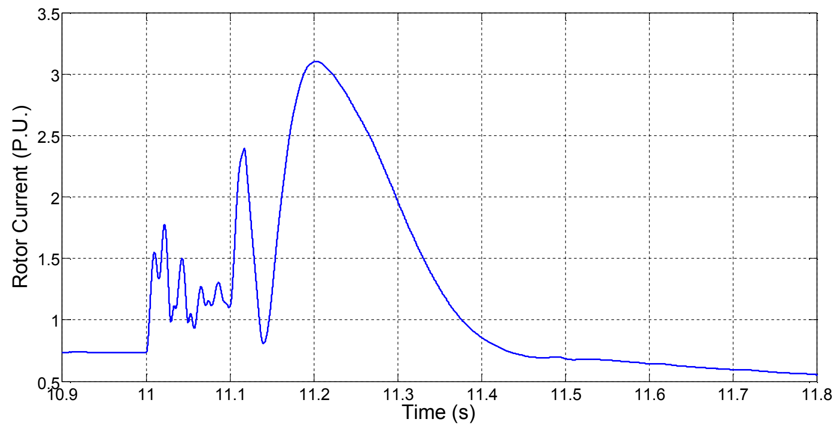



*Figure 6: The peak rotor current*

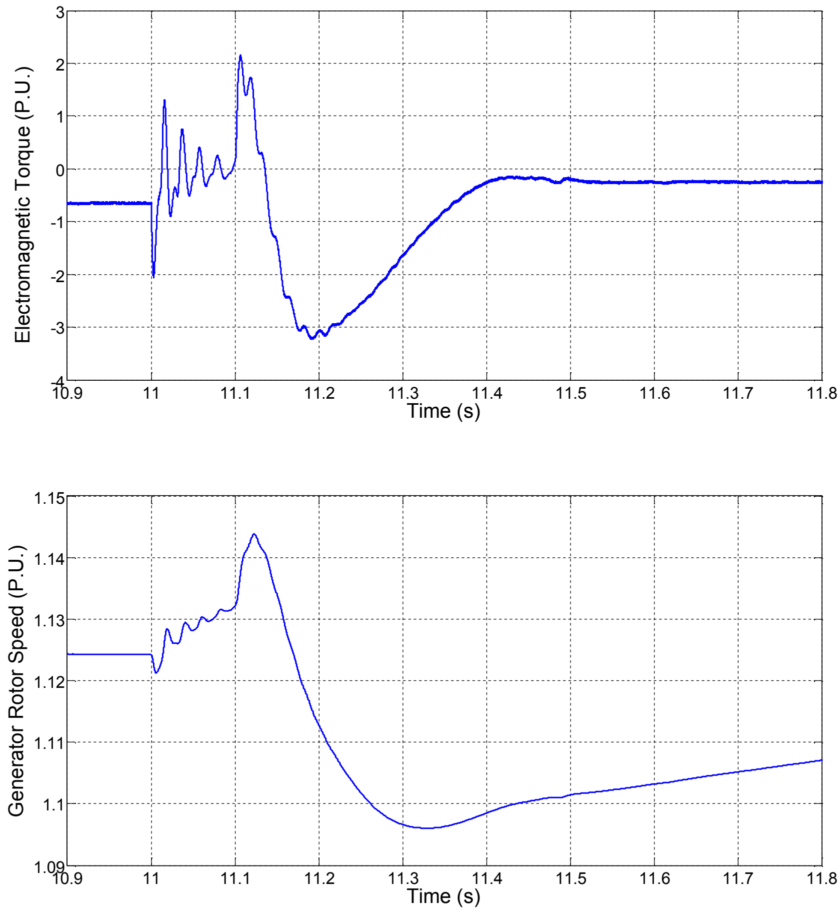



*Figure 7: Electromagnetic torque and generator rotor speed*

## System with DC Chopper Circuit

Same fault is applied to the system but with dc chopper activated. As rotor current or dc-link voltage exceeds the threshold limit an enable signal is fed to switch to connect dc chopper circuit to the system but RSC converter is still connected to the system. When rotor current and dc-link voltage value are within limits, power switch is open and dc chopper circuit is out of the system.

By comparing figure 9 and 5, shows that dc chopper increase the recovery period of the system because more reactive power fed to grid when dc chopper is active to limit dc-link voltage. Shape of dc-link voltage is smoothened as illustrated in figure 8. As shown in figure 10, rotor current is limited by dc chopper activation. Transients in generator rotor speed and electromagnetic torque decreased in magnitude due to dc chopper activation as portrayed in figure 11.

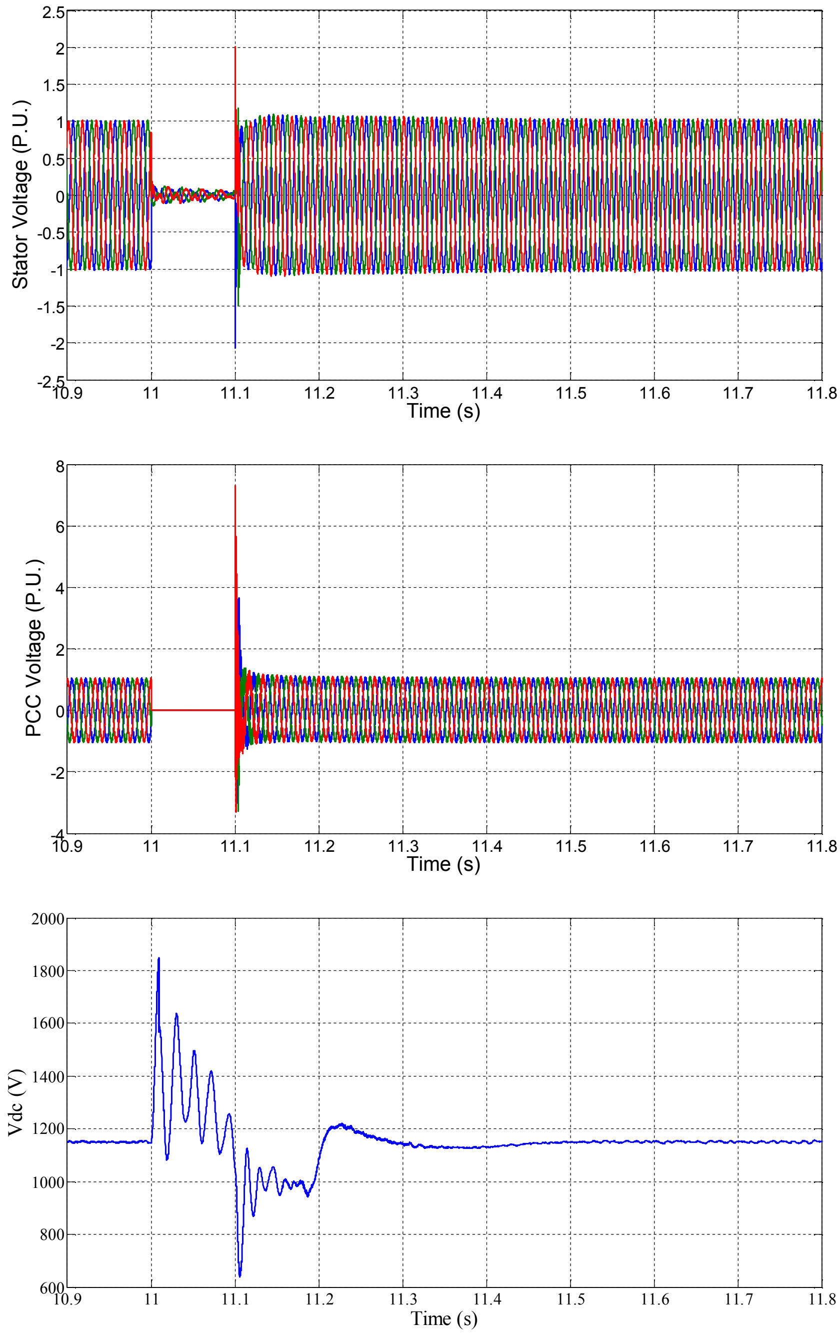
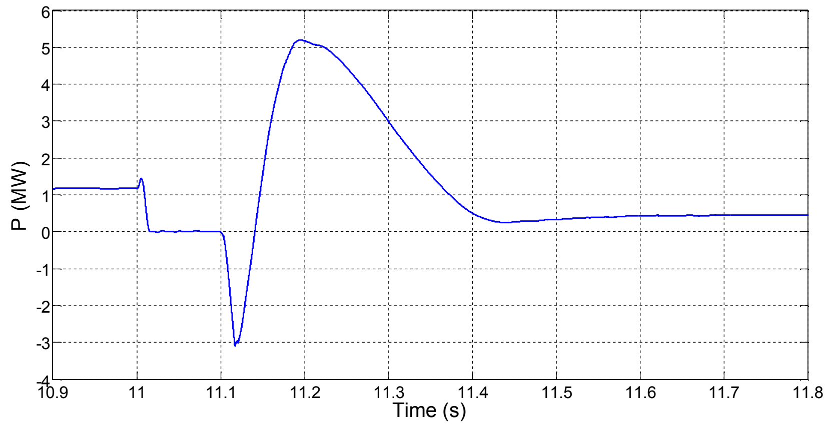



*Figure 8: Stator voltage, PCC voltage, and dc-link voltage*



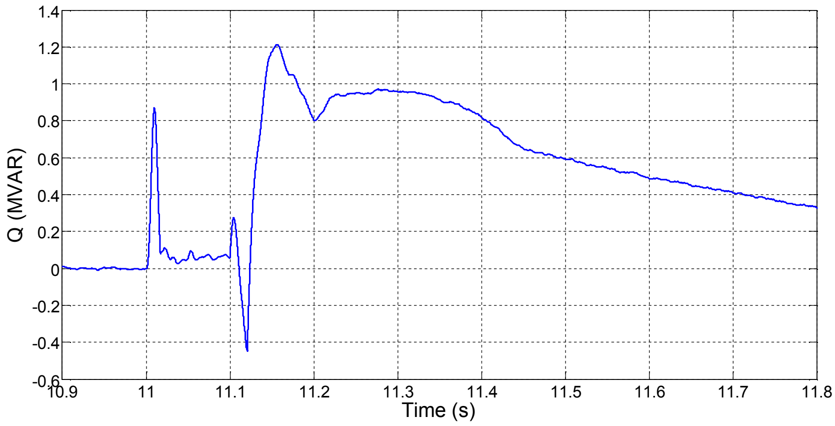
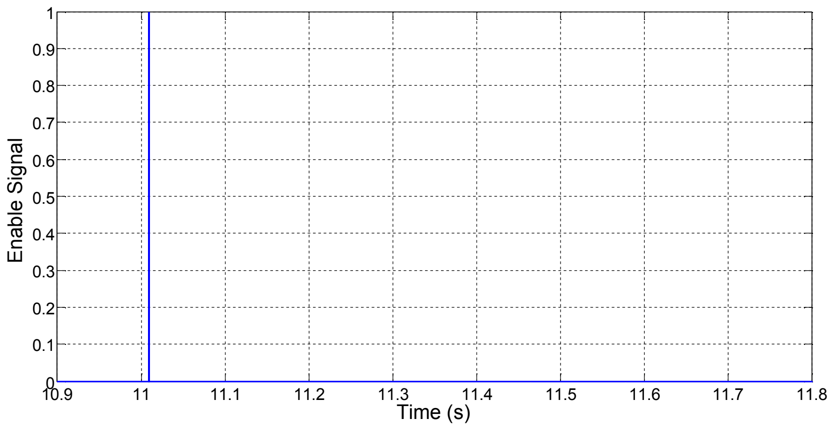




*Figure 9: Active and reactive power fed to grid from the wind turbine*



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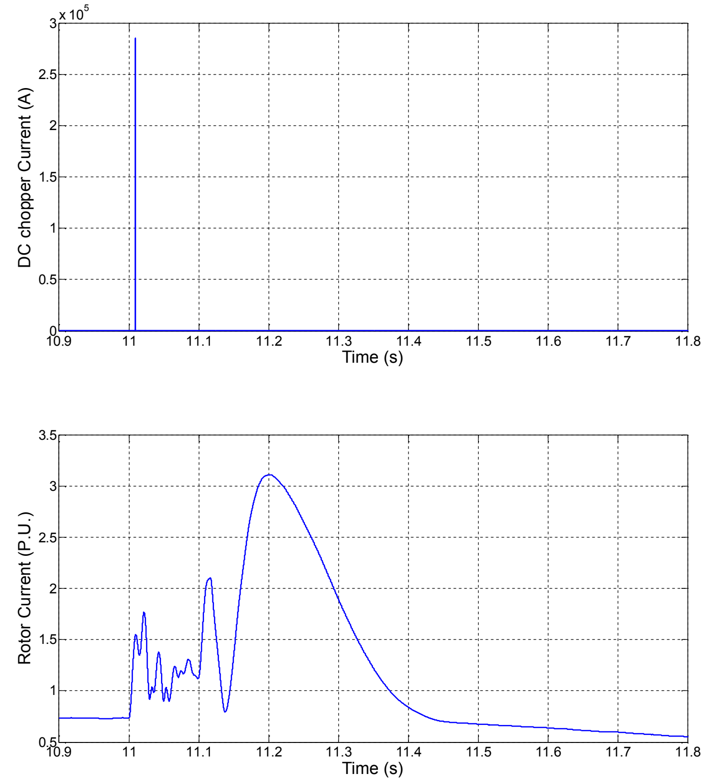


*Figure 10: Enable signal, dc chopper current and the peak rotor current*

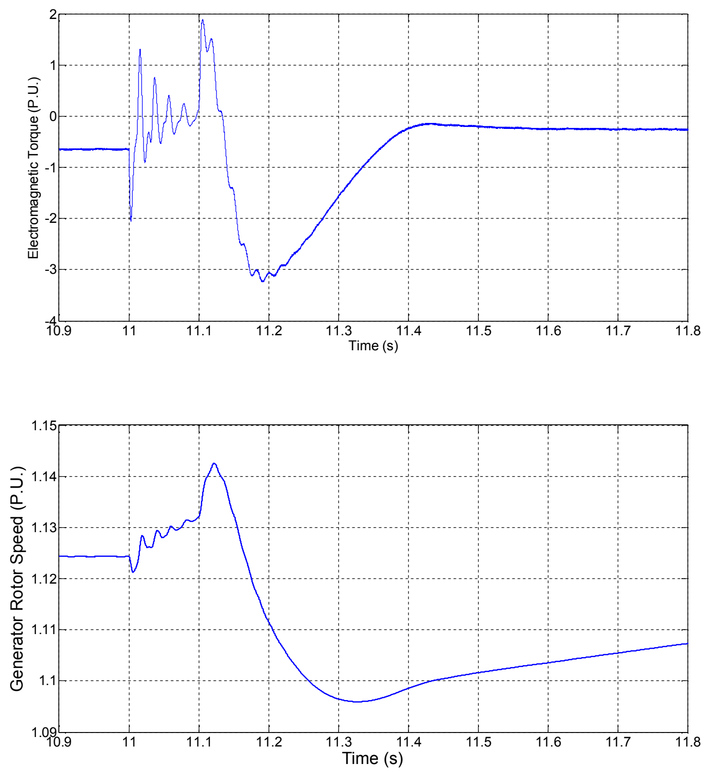


*Figure 11: Electromagnetic torque and generator rotor speed*

## Conclusion

This paper is primarily about control strategy and protection schemes for the DFIG based wind turbine system. A DFIG model is developed in MATLAB-SimPowerSystem, and control strategy is verified. By the use of dc chopper circuit, over voltage in the dc-link voltage and over current in rotor circuit is well limited. In this paper three phase to ground fault at PCC is simulated to examine the system behaviour with and without dc chopper protection.

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